# 3.0 RCM ANALYSIS PROCESS DETAILED DESCRIPTION AND GUIDANCE

- **3.1 RCM Analysis Overview.** The RCM analysis process is summarized by the steps listed below and shown in FIGURE 3-1:
- a. <u>Functional Failure Analysis</u>. Defines equipment functions, functional failure, and EFMs to which RCM analysis may be applied. This is usually accomplished through a FMECA.
- b. <u>RCM SI Selection</u>. Determines which items and/or functions will be analyzed and categorizes the item as either functionally significant or structurally significant.
- c. RCM Decision Logic (includes analysis of Functionally Significant Items (FSIs) and Structurally Significant Items (SI)). Determines failure consequences and PM and potential redesign requirements for SIs.
- d. <u>AE Analysis</u>. Determines data gathering tasks needed to support the RCM analysis and possibly refine the PM program.
- e. <u>Packaging of PM Requirements</u>. Determines the optimum grouping of PM requirements at all levels of maintenance based on economical, operational or logistically feasible considerations.
- 3.2 FMECA. The FMECA identifies (1) the equipment item (or system/sub-system), (2) its functions, (3) functional failures, (4) EFMs, (5) effects of the failure on the item, system, and end item, and (6) failure detection method. RCM analysis is then used to determine if there is some type of PM task which will reduce or prevent these consequences of failure for each failure mode. MIL-STD-1629A provides instructions for performing a FMECA.

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MIL-STD-1629A provides a detailed description of FMECA data elements. The IRCMS software can be used to actually perform the MIL-STD-1629A FMECA (Task 103) or a previously performed FMECA can be entered into IRCMS for the purposes of RCM analysis. Paragraph 2.3.1 provides additional information on FMEA/FMECA and development of associated ground rules & assumptions.

**3.3 RCM SI Selection.** SI selection is the process of determining which systems, subsystems, WRAs, and/or functions will be subject to RCM analysis based on safety, operational and economic considerations.

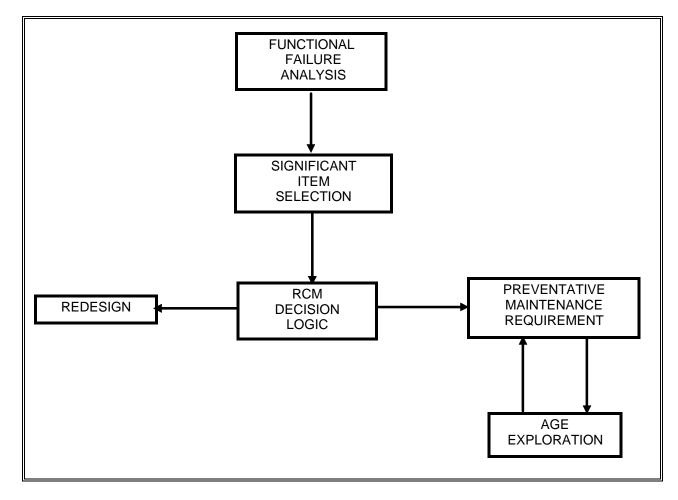


FIGURE 3-1. RCM Analysis Process

- 3.3.1 New Versus In-Service Programs. It should be noted that SI selection can be performed before, after, or concurrently with performing the FMECA. For new acquisition programs, a FMECA is typically performed prior to the RCM analysis because the FMECA has many uses besides just the RCM analysis. In this case the SI selection logic is used to limit the application of RCM on items already in the FMECA. For in-service programs, the FMECA is likely to only be performed for the RCM analysis and may be done during or after SI selection. In this case, the SI selection functions functional process is applied to or failures. identified from a functional block diagram (see paragraph 3.3.2) or other list of functions or functional failures and the FMECA is performed only on significant items. An LSA candidate list can be used as starting point for SI selection. MIL-STD-1388-2A provides additional information on the LSA process. Ground rules and assumptions should be developed in the RCM Implementation Plan to clarify the order of these steps for a particular program.
- **3.3.2 Functional Block Diagrams**. Functional block diagrams (or functional breakdowns) are excellent tools for selecting

significant items. A functional block diagram is constructed by dividing equipment into functional systems, similar to the two digit work unit code (WUC) systems for aircraft. Each of these systems is then further broken down into progressively lower levels of indenture (subsystems, WRA, or SRA), see FIGURE 3-2. This breakdown is useful to visualize the functional relationship of the various components to each other, to the higher levels of indenture, and to the end item. Every attempt should be made to accomplish the RCM analysis at the highest level of indenture possible, typically the system or subsystem level. A RCM

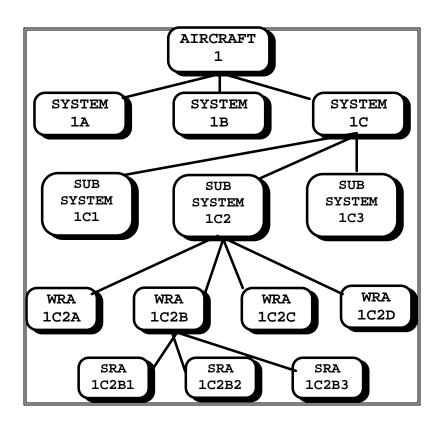


FIGURE 3-2. Functional Breakdown

analysis should be performed at the level necessary to ensure a complete analysis, but should not be performed on too large of a scale in order not to complicate the overall analysis process. (SSIs should be analyzed below the subsystem level.)

**3.3.3 RCM SI Selection Logic**. FIGURE 3-3 is the logic process used to determine if an item/function requires RCM analysis by evaluating the functions that the item provides to the end item. It divides items into three groups: structurally significant, functionally significant, and non-significant based on answers to the SI selection logic questions described below.

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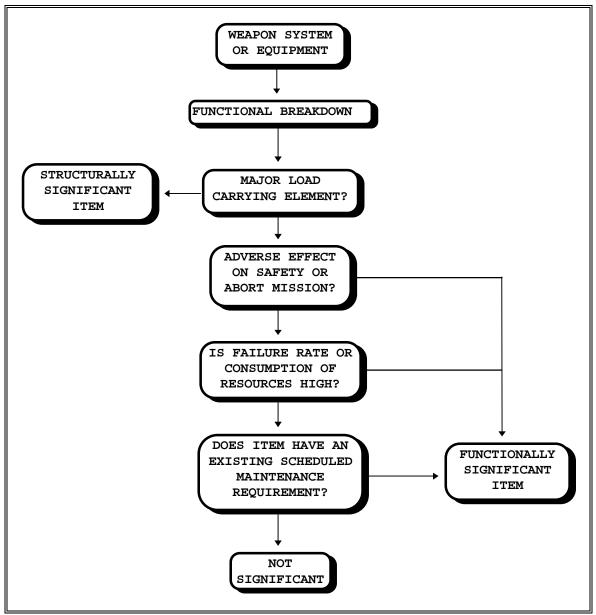
SI selection is accomplished in IRCMS by answering four questions on the FMECA function screen. These questions may be answered at the time functions are entered or later; however, they must be answered prior to beginning the RCM analysis.

a. Question 1: Does the function of the structural element carry major ground or aerodynamic loads? The intent of this question is to evaluate all item functions subjectively with regard to ground or aerodynamic loads. This includes system components with structural functions such as actuator housings, pistons, rod ends, connectors, hinges, bellcranks, etc.

SSIs are identified to analyze structure (load carrying elements) whose failure, if left undetected, would have an adverse effect on safety. Safety is affected if surrounding structure or backup elements can not carry the remaining load for the design life of the aircraft after the element in question fails (residual strength reduced to less than design limits). Structural items, including equipment with structural functions, for which functional failure will not affect safety are treated as FSIs. SSIs should be chosen carefully because once designated as an SSI, some PM task or redesign will be required.

SSIs which also have non-structural functions such as actuator housings, pistons, rod ends, connectors, hinges, etc. should be analyzed as both an SSI and FSI. To accomplish this in IRCMS, add structural and non-structural functions for each item as required.

b. Question 2: Does loss of the function cause an adverse affect on operating safety or abort the mission? If question 1 was answered "No", this question must be answered. Analyze functional failures to determine whether they have safety consequences or would cause mission abort. Answer this question for each functional failure (resulting from the failure cause which is the EFM) of a given function. If the function has a Severity Classification (SC) of I, it shall be identified as safety. If the function has a SC of II, it will be identified as either safety or mission abort. In either case, a yes answer will be given and the item shall be listed as a FSI. Secondary damage must also be considered in answering this question. If a function/failure is hidden, the condition that causes the failure to become evident shall be assumed to have occurred.



c. <u>Question 3</u>: Is the actual or predicted failure rate of the item or consumption of resources high? Thresholds for high failure rates and consumption of resources should be provided in Analysis Ground Rules and Assumptions. Determination of what constitutes a high failure rate may be different for different safety hazard severity classifications.

# FIGURE 3-3. FSI/SSI Selection Diagram

"Consumption of resources high", implies that the failure is of a high cost item (cost of the item or manpower used to replace it) which may or may not fail frequently, or of an item which fails

often but may not be a high cost item (repair or manpower). Failures which cause significant loss of equipment availability would also be considered a "high consumption of resources". Finally, if the functional failure results in any primary or secondary damage that causes high repair costs or out of service time then consumption of resources would also be high.

d. Question 4: Does the item have an existing PM requirement? For in-service equipment review the current scheduled maintenance requirements. For new acquisitions, the Baseline Comparison System (BCS) should be used as a primary

DECISION QUESTION	DEFAULT ANSWER IF UNCERTAIN	POSSIBLE ADVERSE EFFECTS OF DEFAULT	
SI Identification  Is the item significant?	Yes - Classify item as significant	Unnecessary analysis	
Failure Consequence <u>Evaluation</u>			
FSI Decision Logic Question 1  FSI Decision Logic Question 2  FSI Decision Logic Question 3	No - Classify failure as hidden  Yes - Classify item	Unnecessary maintenance or redesign Unnecessary redesign	
	as safety critical	or maintenance that is not cost effective	
	Yes - Classify item as safety hidden failure	Unnecessary redesign or maintenance that is not cost effective	
EVALUATION OF PROPOSED PM TASKS			
Is a servicing or lubrication task applicable/effective	Yes - Include task at default interval	Unnecessary maintenance	
Is an OC task applicable/effective	Yes - Use short enough intervals to make task effective	Maintenance that is not cost effective	
Is HT task applicable/effective	Yes - Use real and	Maintenance that is	

Is a combination of	applicable data to establish life limit	not cost effective
tasks applicable/ effective	Yes - Include on OC	Maintenance that is not cost effective
	task with a HT task	

FIGURE 3-4. Default Decision Logic Chart

determinant. This does not necessarily imply that the FMECA and RCM analyses from like equipment are applicable, but does indicate that this item is significant from a maintenance perspective and should be subject to analysis. If the answer to any of these questions is unknown, use FIGURE 3-4 to provide conservative default answers to the logic questions.

**3.4** RCM Analysis of Functionally Significant Items. After an item is determined to be functionally significant through the FSI/SSI Selection Logic (see FIGURE 3-3), appropriate PM tasks are evaluated for applicability and effectiveness (see FIGURE 3-6).

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Applicability determines if the type of task is appropriate for preventing the failure mode, and depends on the failure characteristics of an item. Effectiveness determines if the task can be performed at a reasonable interval that will (1) reduce the probability of failure to an acceptable level (when safety is a concern), or (2) be more cost effective than allowing the failure to occur (when safety is not a concern). The RCM logic (and IRCMS software) will determine task applicability based on data provided by the analyst. If a task is applicable, the RCM logic allows the analyst to develop an "effective" PM task. It is then up to the analyst to decide if the calculated PM task interval is actually effective (practical).

The order of task evaluations for each logic path represents an assumption that the first task evaluated would be the most desirable from a cost-effectiveness perspective and each subsequent task would be increasingly less cost-effective. This assumption does not always hold true and additional tasks should be given at least a cursory evaluation for cost-effectiveness even if one task is found applicable and effective. Unlike previous versions of RCM software, IRCMS 5.3.1 now allows the consideration of more than one PM task.

The criteria for determining applicability and effectiveness are summarized in FIGURE 3-6. Information from the FMECA, along with

data from any available source, should be used to evaluate each task. If the answer to any of the task evaluation questions is unknown, use FIGURE 3-4 to provide a conservative route through the logic.

**3.4.1 Failure Consequences**. After the SI's failure modes have been properly identified through the FMECA, the first three RCM decision diagram questions can be answered (see FIGURE 3-4) for each failure mode. These answers determine the consequence for each failure and identify which branch of the decision diagram to follow during task evaluation. In answering these three questions, use the data provided in the FMECA.

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a. Question 1: "Is the functional failure occurrence evident to the crew or operator while performing normal duties?" To help determine if the functional failure is evident, refer to the item description, compensating provisions, and failure detection method on the FMECA. The FMECA should identify design features, instruments, operational characteristics, or warning lights which make a failure evident to the operator. The functional failure of an item is considered not evident to the operator if either of the following situations exist:

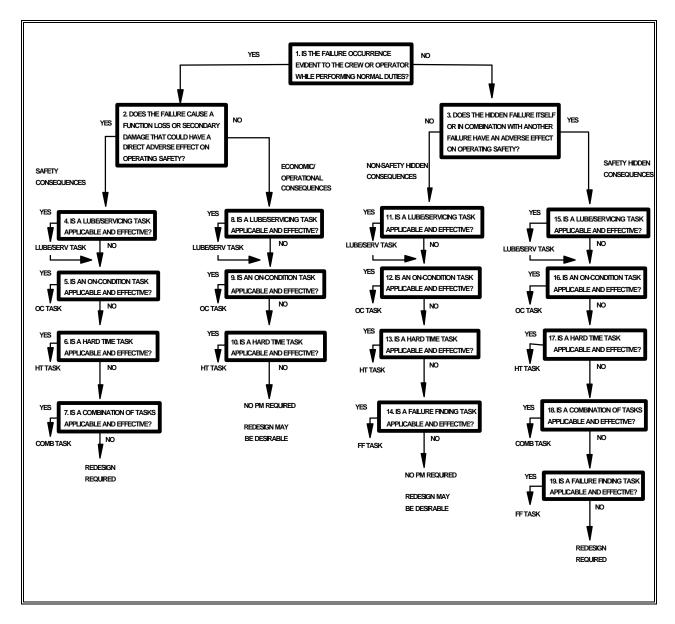


FIGURE 3-5. RCM Decision Diagram For FSIs

- (1) The function is normally active whenever the system is used, but there is no indication to the operator when the function ceases to perform.
- (2) The function is normally inactive and there is no prior indication to the operator that the function will not perform when called upon. The demand for the inactive function will usually follow another failure and the demand may be activated automatically or manually.

A functional failure is evident only if it can be detected by the crew/operator (not the maintenance technician) that is responsible for the phase of the mission in which the function is

	FAILURE CONSEQUENCES				
	SAFETY	OPERATIONAL	NON-SAFETY	SAFETY HIDDEN	
		/ECONOMICS	HIDDEN	FAILURE	
			FAILURE		
	EF	EFFECTIVENESS CRITERIA FOR ALL TASKS			
	Must reduce risk	Must be cost ef	fective;	Must reduce risk	
	of failure to an	Cost of preventive		of multiple	
	acceptable level	maintenance mus		failures to an	
		than cost of op	erational	acceptable level	
		loss and/or cos	st of repair		
TASK		APPLICABILI	TY CRITERIA		
SERVICING/	The replenishment of	of the consumable	e or lubricant m	must be due to	
LUBRICATION	normal operation ar	nd called for by	the design		
ON-CONDITION	1. Must be possible	le to detect redu	aced failure res	sistance	
(OC)	2. Must have a definable, detectable potential failure condition				
	3. Must have a consistent age from potential failure to functional				
	failure				
HARD TIME	1. Must have	1. Must have a		1. Must have	
(HT)	minimum age	conditional pro		minimum age below	
	below which no	failure shows a	ı rapid	which no failures	
	failures will	increase		will occur	
	occur		_		
		2. A large percentage of items must survive to this		2. (REWORK ONLY)	
	2. REWORK ONLY)			Must be possible	
	Must be possible	age		to restore to an	
	to restore to an			acceptable level	
	acceptable level	3. (REWORK ONLY) Must be		of failure	
	of failure	possible to restore to an		resistance	
	resistance	acceptable level of failure			
		resistance			
FAILURE				is applicable and	
FINDING			effective		

FIGURE 3-6. Applicability and Effectiveness Criteria Summary

used. For some items, particularly certain support equipment and some electronics racks, the maintenance technician is the operator, and the RCM analysis for such items should reflect this.

For a functional failure to be evident, failure indications (i.e. gauges, warning lights, fault codes, crew sensing, etc.) must be obvious to the operator while performing normal duties, without special monitoring. Normal duties for the crew are those procedures typically performed to complete a mission. For the air crew, these duties do not include pre-operation, post-operation, or walk around inspections since the inspections do not ensure operational capability of the equipment while performing its mission. However, operational checks of systems during operation are considered valid methods of detecting failures if the checks are part of normal procedures.

Some systems are operated full time, others once or twice per mission, and some less frequently. All of these duties, providing they are done at some reasonable interval, qualify as "normal". On the other hand, most emergency operations are done at very infrequent periods. Therefore, they cannot be classified as "normal" duties. Justification for this question should include the means the operator has of detecting the failure. In the case where no data is available or the answer is uncertain, the default logic answer is used (see FIGURE 3-4).

b. Question 2: "Does the engineering failure mode cause a function loss or secondary damage that could have an adverse effect on operating safety?" To determine the effect on operating safety for non-hidden failures, consider this question in parts: first, the loss of the function (functional failure) and second, the effects of secondary damage.

If question 1 was answered "Yes", the failure is evident (non-hidden). Refer to the severity classification, failure effects and compensating provisions provided on the FMECA, and consider the following when answering this question for evident failures:

- (1) The EFM (mechanism of failure as defined in MIL-STD-1629A) must achieve its effect, by itself, and not in combination with other EFMs. In other words, the EFM must independently be able to cause the adverse effect on operating safety. However, possible secondary damage caused by the EFM should be considered.
- (2) The direct consequence of an EFM is an extremely serious or possibly catastrophic condition (Category I or Category II).
- (3) "Operating safety" refers to normal operations during the period of time when the unit is powered-up with the intent to perform its mission. For support equipment the "operating safety" regime is performance of a servicing action until the unit is secured at its designated place and power is off.
- (4) The EFM must affect a function that is not protected by redundant items or protective devices. That is, if the function is protected by a redundant item or by a protective device, its failure does not have a direct adverse effect on operating safety. An example of a protective device is a delta pressure bypass valve in an engine oil supply line filter. When the bypass valve activates, the filtering function is lost, but the function of oil flow is protected. Therefore, a clogged oil filter, if protected by a bypass valve, will not cause bearing or engine seizure. In this case, it does not have a direct adverse effect on operating safety.

A "Yes" answer to this question will require some task to prevent the safety consequence or redesign of the item to get rid of the failure mode. A "No" answer indicates there are economic or operational consequences. If the answer to any of the task evaluation questions is unknown, use FIGURE 3-4 to provide a conservative route through the logic.

If question 1 is answered "No", the failure mode is hidden and effect on safety must be considered differently. Safety effects are similar to evident failures, except that the effect of the failure is not immediate.

For hidden failures, refer to the FMECA severity classification, failure effects and compensating provisions when answering question 2, and consider two areas:

- (1) First, analyze the hidden failure to determine if it has an adverse effect on operating safety. This adverse effect on safety can result when the function is called upon, not when the EFM occurs. If the adverse effect on safety occurs when the EFM occurs, the functional failure is not really hidden.
- (2) Second, if the hidden failure by itself, does not have an adverse effect on safety, evaluate a combination of failures. In this case, the hidden failure adversely affects safety only when it occurs in combination with one additional failure. This additional failure occurs after, and may be precipitated by the hidden failure. The second failure must be in a related system, a back-up to the system in which the hidden failure occurs, or the failure of a primary system for which the hidden failure is a back-up.
- A "Yes" answer indicates there are safety hidden failure consequences. If a combination of failures is identified, include a description of the additional condition in the justification. A "No" answer indicates the failure has non-safety hidden failure consequences, which only involve economic or operational effects. If the answer to any of the task evaluation questions is unknown, use FIGURE 3-4 to provide a conservative route through the logic.
- **3.4.2** Serv/Lubrication Tasks. As shown in FIGURE 3-5, servicing and lubrication tasks must be evaluated for each EFM. These tasks, by themselves, do not necessarily satisfy the complete requirement for PM; other tasks must also be evaluated.

- a. <u>Applicability</u>. Servicing tasks are applicable if replenishment of a consumable (such as oil, gas, oxygen, etc.) is required due to normal operation to avoid the failure mode. A lubrication task is applicable if the design of the item requires periodic application of non-permanent lubricant to avoid the failure mode.
- b. <u>Effectiveness</u>. When an applicable task is found, its effectiveness must be evaluated. A servicing or lubrication task is effective if it fulfills a design requirement and can be performed at a reasonable interval. Justification must be provided to substantiate the identified task interval. The servicing interval is based upon the rate at which the item is consumed. Lubrication intervals are generally based on the design of the lubricant. Lubricant military specifications or design specifications should provide the required information for lubricant life under various conditions.
- **3.4.3 On-Condition (OC) Tasks**. OC tasks are evaluated for all FSI EFMs. An OC task is a scheduled inspection for a potential failure condition (symptom of failure). OC tasks call for corrective action to be performed "on the condition" that the item in question does not meet a required standard. By repairing or removing from service only those items that are about to fail, OC tasks maximize the useful life of individual items. DOD Report AD-A085450, "Designing On-condition Tasks for Naval Aircraft" contains additional information on OC tasks.

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- a. <u>Applicability</u>. The criteria for OC task applicability is determined by answering three question in IRCMS:
- (1) It must be possible to detect reduced failure resistance for a specified EFM. Reduced failure resistance is when the failure mode has begun to occur and can be detected, but the component is still performing its function. Question 1 refers to this condition. Answer "Y" or "N". If "Y", provide the specific means such as "Visual inspection for cracks". Be as specific as possible.
- (2) It must be possible to define a potential failure condition that can be detected by an explicit task. Question 2 refers to this criterion. Answer "Y" or "N" and provide numerical values for the potential and functional failures when possible such as ".01 inches" and ".25 inches" for cracks. The potential failure condition may indicate a maximum condition allowed to remain in service such as "wear of .100 inches.", or a minimum detectable condition such as a ".01 inch crack".

(3) There must be a reasonably consistent age interval between the time of potential failure and the time of functional failure. Question 3 refers to this criterion. Answer "Y", "N", or "D". Answer "D" if you have determined a value based on default data or methods. This will require the evaluation of an AE task to verify the default data. If answering "Y" or "D", provide the interval and units for the interval.

If all three of the above criteria are met, describe the applicable task. The task should identify what is being performed, the condition being detected, and as specifically as possible, the location of the potential failure, for example, "Inspect rear wing spar lower flange for cracks at Wing Station 123.4".

Potential to functional failure intervals are typically one of the most difficult values to determine in RCM analyses. Fracture mechanics and fatigue test data, which provide detectable to critical crack life, are useful for crack failure modes. Examples of other available sources of this interval include component tests, data from Aircraft Data Recorders/Engine Monitoring Systems which measure data such as vibration over time, etc. Unfortunately, most other failure modes rarely have simple analytical solutions or available data and require default methods. Default methods include using a current PM task that has proven to be effective and working backwards from the current task interval, or using intervals from like and similar equipment on other aircraft. Chapter 5 provides additional information on the determination of potential to functional failure intervals.

b. <u>Effectiveness</u>. By definition, if an OC task is applicable, there is a task that can be performed at some interval to preclude the failure. Determining effectiveness essentially amounts to determining the longest task interval that still meets the applicability criteria and deciding whether performing the task at this interval is "practical".

The preliminary (engineering) task interval is the interval from potential to functional failure divided by some number. For safety failure modes, this number of inspections "n" is determined by calculating the minimum number of inspections within the interval from potential to functional failure that reduces the actual probability of failure to less than or equal to the acceptable probability of failure. Safety hidden failure modes are similar except that the actual probability of failure times the probability of the condition that make the failure become evident (probability of multiple failures) must be less than or equal to the acceptable probability of failure.

The number of inspections "n" is calculated in IRCMS by  $n = \ln(Pacc)/\ln(1-\Theta)$  where Pacc is the acceptable probability of failure and  $\Theta$  is the probability of detecting a potential failure in one inspection (i.e. 90% implies  $\Theta$  = .9) assuming that a potential failure exists. This is only one method of calculating task intervals; any other analytically justifiable method could also be used.

For economic/operational and non-safety hidden failure consequences, the effectiveness criteria is cost related. purely economic consequences, a task is effective if it costs less than the cost of the failure it prevents. For operational consequences, a task is effective if its cost is less than the combined cost of operational loss and the failure it prevents. Whenever practical, a cost benefit analysis, whether formal or informal, should be performed to determine whether a certain task is cost effective and identify the optimum interval at which to perform the task. Paragraph 4.3.4 provides detailed information on RCM cost benefit analysis.

**3.4.4** Hard Time (HT) Tasks. HT tasks are evaluated for all failure modes which do not have applicable and effective OC tasks. A HT task is simply a scheduled removal of an item or safe life limit of an item. There are two types of HT tasks: rework and discard. If an item can have an acceptable level of failure resistance restored by rework or remanufacture, a rework task is evaluated. If the item cannot be reworked or remanufactured, a discard task is evaluated.

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- a. <u>Applicability</u>. The applicability criteria for HT tasks is determined by answering three questions in IRCMS:
- (1) For a rework task, the item must be capable of having an acceptable level of failure resistance restored for the specific EFM under analysis. Question 1 determines whether a rework task or discard task will be considered. "Y" will result in the evaluation of a rework task; "N" will result in the evaluation of a discard task.
- (2) The item must exhibit wearout characteristics identified by a rapid increase in the conditional probability of failure (see FIGURE 3-7). Question 2 will ask whether this wearout age exists and its value. If a "D" was entered in the first part of the question, the wearout age is a default value that should be resolved through an AE task.
- (3) A large percentage (100% when safety is involved) of the items must survive to the wearout age for the task to be applicable (see FIGURE 3-7). Question 3 asks for the percentage surviving to this wearout age. The definition of "large

percentage" is left to the analyst; however, the definition should be included in the IRCMS or ground rules and assumptions.

If all three of the above criteria are met, describe the applicable task. The task should identify what is being performed and the item being removed as specifically as possible, for example, "Remove NLG shock strut for rework".

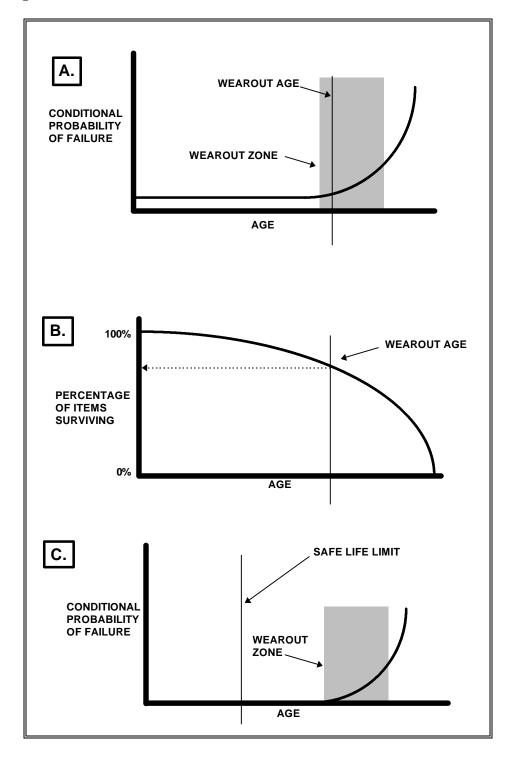


FIGURE 3-7. Applicability Criteria For Hard Time Tasks

b. <u>Effectiveness</u>. Like the OC task, if a HT task is applicable, it can be performed at some interval to preclude the failure. Determining effectiveness means finding the longest task interval that still meets the applicability criteria and deciding whether performing the task at this interval is "practical".

The HT task removal interval is based on the wearout age. When safety is a concern, the removal interval must be well before the wearout age in order to ensure that none of the items will fail in service (actual probability of failure must be less than or equal to acceptability of failure). For non-safety failure modes, a cost benefit analysis should be performed to determine the optimal interval. Whenever practical, a cost benefit analysis, whether formal or informal, should be performed to determine whether a certain task is cost effective. Paragraph 4.3.4 provides detailed information on RCM cost benefit analysis.

HT intervals are usually calculated from statistical analysis of failure or test data. Statistical techniques such as Weibull or Log-normal are very useful as are other analysis techniques such as actuarial analysis in the development of HT task intervals. See chapter 5 for additional information regarding analysis tools and techniques.

3.4.5 Failure Finding Tasks. The failure finding task is used only if OC or HT tasks are not applicable and effective for hidden failure (safety and non-safety) modes (see FIGURE 3-5). Because this task is used to detect failures that have already occurred, only combinations of failures are evaluated for safety hidden failure consequences. Failure finding tasks are usually functional or operational checks to verify proper operation of emergency or backup equipment, or indicating systems. Built-intests (BIT) can also be a type of failure finding task. If the hidden failure can be discovered by the failure finding task and corrected before the additional failure occurs, the consequences of the combination of failures is averted. When a BIT or maintenance panel readout detects a latent failure that has no detectable interval from potential to functional failure, the failure finding task will be directly analyzed and the HT task may be omitted.

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a. <u>Applicability</u>. The item must be subject to a functional failure that is not evident to the crew or operator during performance of normal duties. For example, the nitrogen has leaked from the landing gear emergency extension system.

b. <u>Effectiveness</u>. As with OC and HT tasks, if the failure finding task is applicable, there is a task that can be performed at some interval to preclude the failure. Determining effectiveness is finding the longest task interval that still meets the applicability criteria and deciding whether performing the task at this interval is "practical".

A failure finding task interval should be the longest possible interval that will reduce the actual probability of occurrence of the hidden failure, and the failure or condition which makes the failure evident, to an acceptable level. Mathematically,  $Pact \times Pmf \leq Pacc$ , where Pact is the actual probability of failure, Pmf is the probability of the multiple failure or condition which makes the first failure evident, and Pacc is the acceptable probability of failure. One method of calculating failure finding task intervals, applicable for random failures, is to use the formula  $Pf = (1-e^{-(t/MTBF)})$  for each of the unknown probabilities in the above equation and solve for t. Note: If more than one probability is unknown, the resulting equation will be indeterminate and will require an iterative solution.

3.4.6 Age Exploration (AE) Tasks. AE tasks are developed to collect data to refine default decisions or data included in the initial RCM analysis. AE tasks may be actual inspections or tests, or simply reviews of usage or failure data such as 3-M. AE tasks are intended to be of limited duration so that when sufficient data is collected, the RCM analysis will be updated and the AE task deleted. Additionally, the RCM logic provides for assessment of the potential cost-effectiveness and for prioritization of AE tasks. Paragraph 4.3.3 provides detailed information on AE tasks implementation.

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In the evaluation of AE tasks, IRCMS first asks questions relative to the cost and resources required for the task and whether potential benefits out-weigh any additional costs. These questions are usually subjective. Rationale for the answers should be provided where possible. The intent is to ensure that only those tasks which will provide a clear benefit are performed and prioritized.

The second part of the AE task evaluation is the development of the task itself. Some of the information required for development of tasks is further described below:

a. <u>Sample size</u>. Sample size is the number of aircraft, engines, or components that will be subject to the AE task. Sample size will vary depending on the type of task and what information is required. For example, if the task is a test to

failure, the sample size will likely be very small (often one test specimen). Statistical techniques should be used to determine the minimum sample size required for a given situation. Chapter 5 provides additional information on the determination of sample sizes.

- b. <u>Study period</u>. Study period is the length of time the AE task will continue for the entire sample, usually in years or flight hours.
- c. <u>Initial interval</u>. Initial interval is the time when the first inspection, data collection, etc. will be performed on an individual item.
- d. <u>Repeating interval</u>. Repeating interval is the length of time between inspections, data collection, etc. on an individual item.
- **3.4.7** Redesign Decisions. In cases where redesign is required and cannot be immediately implemented, PM tasks deemed "not practical" in the analysis may have to be implemented on a temporary basis until a design change can be incorporated. In other cases where an applicable and effective PM was identified, a redesign may still be cost or operationally beneficial and should be evaluated whenever possible.
- 3.5 RCM Analysis of SSIs. The SSI analysis logic is used to determine PM requirements for items identified as SSIs by the significant item selection process. SSIs are analyzed differently than FSIs because, by definition, all SSI EFMs can potentially affect safety and usually fall into one of three general categories; fatigue damage, environmental damage, and accidental damage. The SSI analysis logic is shown in FIGURE 3-8.
- 3.5.1 Classification of SSI Failure Modes. The first step in the analysis of SSIs is determining whether a given failure mode should be analyzed as a fatigue damage failure mode or an environmental/accidental damage failure mode. Fatigue damage failure modes can include normal fatique crack growth, stress fretting, thermal fatigue, corrosion cracking, composite deterioration, or delamination growth, etc. Environmental damage failure modes can include corrosion, erosion, stress corrosion cracking, etc. Accidental damage failure modes can include induced damage, wear, loose/missing structural fasteners, etc. Note that some failure modes such as stress corrosion cracking could fit into more than one category. The decision of which category to include the failure mode will affect what types of preventive tasks are applicable, how the effectiveness criteria for each task is evaluated, and how task intervals are developed.

### RCM PROCESS/IRCMS GUIDANCE

The first question in the IRCMS SSI section will determine the SSI failure mode classification. In many cases the answer will be obvious, but each of the following factors should be carefully considered prior to making the decision on which category to use.

- a. <u>Fatique Failure Modes</u>. Fatique damage is usually related to usage cycles, typically some type of loading. Therefore, the resulting PM tasks are developed to prevent progressive damage due to normal operating cycles from reaching some critical point. Fatique damage PM tasks will consider factors such as residual strength (RS), life to detectable crack(LDC), item design life (IDL), end item design life (EDL), crack propagation life (CPL), and detectable deterioration (composites).
- b. Environmental Failure Modes. Environmental damage is usually related to exposure time, or to conditional events such as exposure to fire fighting agents. The resulting PM tasks for environmental damage will be based on the time and/or level of exposure to some environmental condition and the item's susceptibility to damage from that condition.

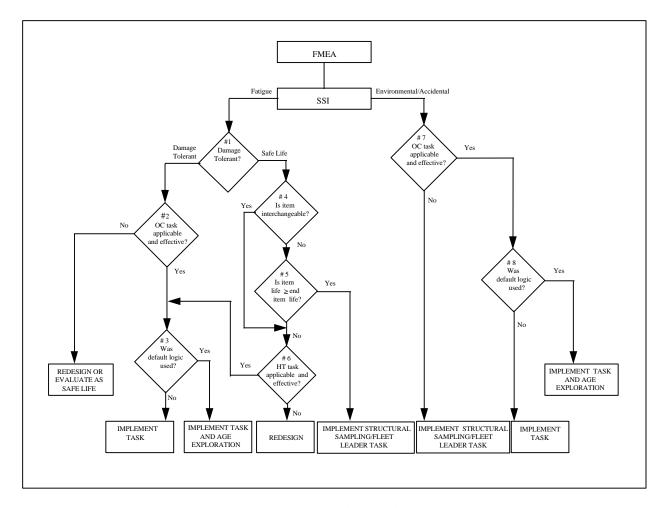


FIGURE 3-8. RCM Decision Diagram For SSIs

- c. Accidental Failure Modes. Accidental damage failure modes are usually random events related to level of usage and susceptibility to damage. While not related to age, the probability of accidental damage occurring at a given time increases as the usage increases. The resulting PM tasks will be based on factors such as the location of the SSI, manufacturing quality control, and operating environment.
- 3.5.2 Classification of Structure Type (Damage Tolerant/Safe-Life). For fatigue failure modes, structure is classified by type (damage tolerant or safe-life) to determine which PM tasks are applicable to the item. For fatigue failure modes of safe life structures, a HT task is usually applicable and will be evaluated for effectiveness. For fatigue failure modes of damage tolerant items, an OC inspection is usually applicable and will be evaluated for effectiveness.

#### RCM PROCESS/IRCMS GUIDANCE

The second question in the SSI section of IRCMS, "Is the item damage tolerant?", determines structure type. If the item is not damage tolerant, it will be identified as Safe Life. Damage tolerant structure is characterized by either slow crack growth or redundant load paths capable of fully sustaining design loads for some period of time with one or more elements no longer carrying any load. Safe-life structure is characterized by a long life to crack initiation. Damage tolerant and safe-life are design characteristics, however, structure designed to be safe-life may have some failure modes that can be managed as damage tolerant and vice-versa. If a "Yes" response is given to this question, further analysis must be done on the damage tolerant branch of FIGURE 3-8. A "No" response prompts further analysis on the safe life branch of the diagram.

**3.5.3 On-Condition (OC) Tasks**. OC tasks are evaluated for applicability and effectiveness for damage tolerant fatigue, environmental, and accidental failure modes.

## RCM PROCESS/IRCMS GUIDANCE

- a. Applicability. Generally, applicability criteria for FSIs applies to SSIs. By definition, if an item is classified as damage tolerant, an OC task should be applicable. Slow crack growth and/or failure of redundant items represent an ideal interval from potential to functional failure. Applicability criteria for SSI OC tasks for accidental/environmental failure modes is exactly the same as for FSI OC tasks.
- b. <u>Effectiveness</u>. A damage tolerant SSI should usually have an effective OC task. If not, the SSI should probably be designated as safe-life. OC task intervals for damage tolerant fatigue and environmental/accidental damage SSI failure modes can be developed using the methods described in the FSI logic section for OC tasks or using SRFs which are further described in paragraph 3.5.7.

FIGURE 3-9 provides an example of how rating factors can be used in determination of task intervals. Ground rules & assumptions can be developed for utilization of rating factors in determining task applicability and effectiveness.

Fatigue Failure Modes

CPL SRF	Inspection Interval
1	1/4 CPL
2	1/3 CPL
3	1/3 CPL
4	1/2 CPL

FIGURE 3-9. Rating Factor Based Inspection Intervals.

**3.5.4** Hard Time (HT) Tasks. Safe-life structure is designed to be used for a certain number of "cycles", and then removed from service prior to failure. Therefore, HT tasks are evaluated for applicability and effectiveness for safe-life SSIs.

### RCM PROCESS/IRCMS GUIDANCE

- a. <u>Applicability</u>. Applicability criteria for FSI HT tasks also applies to SSI HT tasks. In addition, one of the two following criteria, which is determined by answering questions 4 and 5 of FIGURE 3-8, must be met for SSI hard-time tasks:
- (1) The item is interchangeable. Interchangeability would allow an individual item to accrue more cycles than the design life of the end item by changing from one end item to another. Therefore, some means of tracking time against the SSI to ensure it is removed from service prior to failure must be implemented.
- (2) The design life of the SSI is less than the design life of the end item. Obviously, whether or not an item is interchangeable, if its life is less than that of the end item and it is safe-life, a task must be in place to remove the item prior to failure.
- If a HT task is not applicable and effective, then redesign or a fleet leader/structural sampling task is required.
- b. <u>Effectiveness</u>. Effectiveness criteria for FSI HT task applies. However, the intervals for SSI HT tasks are developed using the results of fatigue tests and/or fatigue analysis. Ground rules & assumptions can be developed for utilization of rating factors in determining task applicability and effectiveness.
- 3.5.5 Structural Sampling (SS)/Fleet Leader (FL) Tasks. SS/FL tasks are inspections of limited numbers of SSIs vice the entire population to monitor the aging process of the item and ensure structural integrity is maintained. SS/FL tasks differ from AE tasks in that an AE task is intended to verify default information used to develop a PM task, while SS/FL tasks are meant to verify that no PM is required for critical structural items. Like an AE task, when sufficient data is collected to determine that the failure mode is not realistic, or the item should be reclassified as an FSI, than the RCM should be updated and the task eliminated.

### RCM PROCESS/IRCMS GUIDANCE

- a. Applicability. A SS/FL task is applicable if one of the following applies:
- (1) The failure mode is a fatigue failure of safe-life structure, the SSI is not interchangeable, and it has a design life at least as long as the design life of the end item.
- (2) The failure mode is an accidental or environmental damage failure mode and an OC task is not applicable and effective.
- b. <u>Effectiveness</u>. To be effective, an SS/FL tasks must provide sufficient data to ensure structural integrity is maintained. As with AE tasks, statistical techniques should be used to determine adequate sample sizes and intervals.
- **3.5.6 Age Exploration Tasks.** Paragraph 3.4.6 applies to the evaluation of SSI AE tasks as well as FSI AE tasks.
- 3.5.7 Structural Rating Factors (SRFs). SRFs are one method of determining a SSI's relative importance to other SSIs based on susceptibility to fatigue, environmental, and accidental damage. Structural rating factors can be used to assess applicability of tasks and to determine default inspection intervals. The ratings range from 1 (most susceptible) to 4 (least susceptible). Susceptibility to each type of damage can be broken down into several sub-categories. After this is done, an average rating factor is calculated for each type of damage which can then be used for determining default task intervals. FIGURE 3-10 provides а structural rating factors table for metallic structures. FIGURE 3-11 provides a structural rating factors table for composite materials. Any rating factor table used should be included in the Ground rules and assumptions section of the RCM Implementation Plan for a given program.

FATIGUE RATING FACTORS	1	2	3	4
A) RESIDUAL STRENGTH (RS), percent	Less than 100 %	100 % - 125 %	126 % - 150 %	Greater than 150 %

of damage tolerant load					
B) LIFE TO DETECTABLE CRACK (LDC), percent of EDL	Less than 100 %	100 % - 110 %	111 % - 120 %	Greater than 120 %	
C) CRACK PROPAGATION LIFE (CPL), percent of IDL	Less than 20 %	21 % - 40 %	41 % - 60 %	Greater than 60 %	
ENVIRONMENTAL RATING FACTORS	1	2	3	4	
A) MATERIAL TYPE	Magnesium	Forged AI, dissimilar metals	Clad AI, Steel, Titanium	Stainless steel	
B) SURFACE PROTECTION	Bare	Primer	Anodized, painted	Coated, plated	
C) EXPOSURE					
Internal item	Human waste	Trapped fluid	Vented	Sealed	
External item	Salt water	Air pollutants ground water	Rain	Dry air	
ACCIDENTAL RATING FACTORS	1	2	3	4	
A) DESIGN, MANUFACTURER ERRORS	Complex assembly, difficult fabrication	Complex assembly, simple fabrication	Simple assembly, difficult fabrication	Not susceptible	
B) OPERATIONS (consider both ground and flight operations)	Carrier	Ashore, training, high sortie rate	Ashore, low sortie rate	Not susceptible	
C) LOCATION	External, ground access	External, special access	Internal, accessible	Internal, covered, heavy surface protection	

FIGURE 3-10. Structural Rating Factors (Metallic Structures)

FATIGUE RATING FACTORS	1	2	3	4
A) RESIDUAL STRENGTH (RS), percent of damage tolerant load	Less than 100 %	100 % - 125 %	126 % - 150 %	Greater than 150 %
B) LIFE TO DETECTABLE DETERIORATION (LDD), % of EDL	Less than 100 %	100 % - 110 %	111 % - 120 %	Greater than 120 %
C) DETERIORATION PROPAGATION LIFE (DPL), % of IDL	Less than 20 %	21 % - 40 %	41 % - 60 %	Greater than 60 %
	T	T		T
ENVIRONMENTAL RATING FACTORS	1	2	3	4
A) MOISTURE	Item is honeycomb with two of the following: a) external b) regionally low c) enclosed area	Item is honeycomb with one of the characteristics listed in category 1	All honeycomb not covered by the first two categories, cored, or adhesive bonds cured at 200E F or less	Non-honeycomb, Not cored
B) HEAT	Near heat source (external or internal)	External	Internal cockpit area, sunlight	Internal away from heat source
C) EROSION/ ABRASION	Leading edges and external bottom surfaces	Exposed cabin surfaces	External walkways	Not susceptible
D) CORROSION	Carbon/Magnesium or similar	Carbon/Aluminum or similar	Carbon/Steel/Titanium, or similar	Carbon/Carbon or no effect
	<u> </u>			<u> </u>
ACCIDENTAL RATING FACTORS	1	2	3	4
A) DESIGN, MANUFACTURER ERRORS	Enter average value as determined from Fabrication and Assembly Evaluation below			
(Fabrication and Assembly)	Any process not involving	Co-cured, not automated	Co-cured, automated; or	Laminate, automated
* Process Type * Complexity	co-curing or lamination  Complex assembly, difficult	Complex assembly, simple	Laminate, not automated Simple assembly difficult	Simple assembly,
	fabrication	fabrication	fabrication	simple fabrication
* Accessibility  * Material Inspectability	None Sound attenuating X-ray opaque	One side Sound attenuating X-ray transparent	Two sides Sound transmitting X-ray opaque	Complete Sound transmitting X- ray transparent
B) OPERATIONS	Carrier	Ashore, training, high sortie rate	Ashore, low sortie rate	Not susceptible
C) LOCATION	External, ground access	External, special access	Internal, accessible	Internal, covered, heavy surface protection

FIGURE 3-11. Structural Rating Factors (Composite Materials)